



## **Atmospheric boundary layer wind profile at a flat coastal site - wind speed lidar measurements and mesoscale modeling results during a summer period**

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Atmospheric Boundary Layer wind profile at a flat coastal site –  
wind speed lidar measurements and mesoscale modeling  
results during a summer period

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Tall Wind and VSABLA Projects

## The problem

The wind profile above the surface layer up to 1 kilometer is presently a challenge for

- meteorological forecasts
- wind energy assessment studies
- air pollution applications
- Aviation
- mesoscale models validation, etc

as high resolution (in time and space) measurements were rarely available until recently.

Additional complexity is related with coastal areas!

## Outline

- **Case studies using wind profiler data**
- **Climatology of the vertical profiles of wind and turbulence – long range wind lidar data with high resolution in space and time in coastal area**
- **First results and future work**

## Case studies using wind profiler data

The mesoscale meteorological models have difficulties to predict the profiles, due to complex phenomena taking place in nature that are not accounted for in the ABL parameterizations currently used.

Worldwide an effort is going on to emphasize the important role of boundary layer research in various direct applications, such as wind energy, air pollution, aviation and in weather forecast models.

**A profile evaluation study started recently within COST728,**

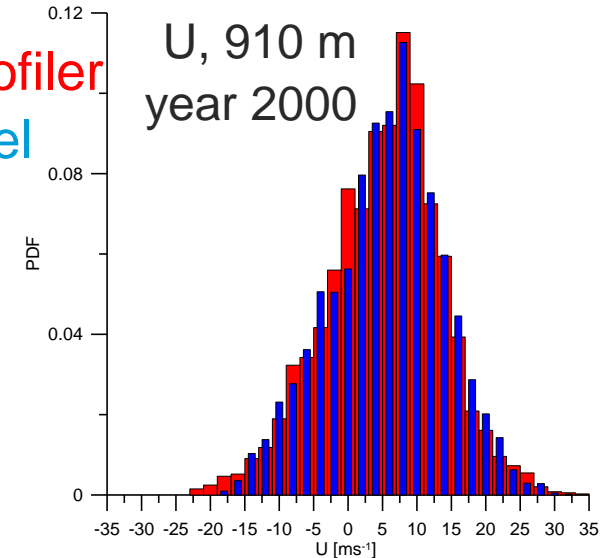
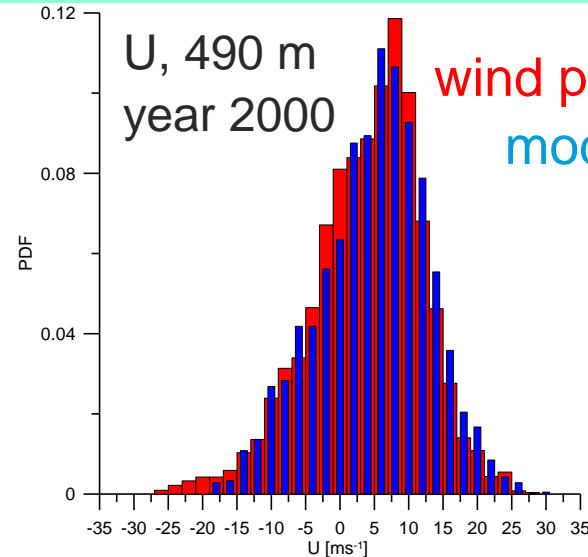
Using windprofiler data in time and frequency domain for the evaluation of meteorological drivers employed in chemistry transport

Modelling (ISTP09 -International Symposium on Tropospheric Profiling, 19-23/10/2009, Delft, RIVM, KNMI, TU-Delft)

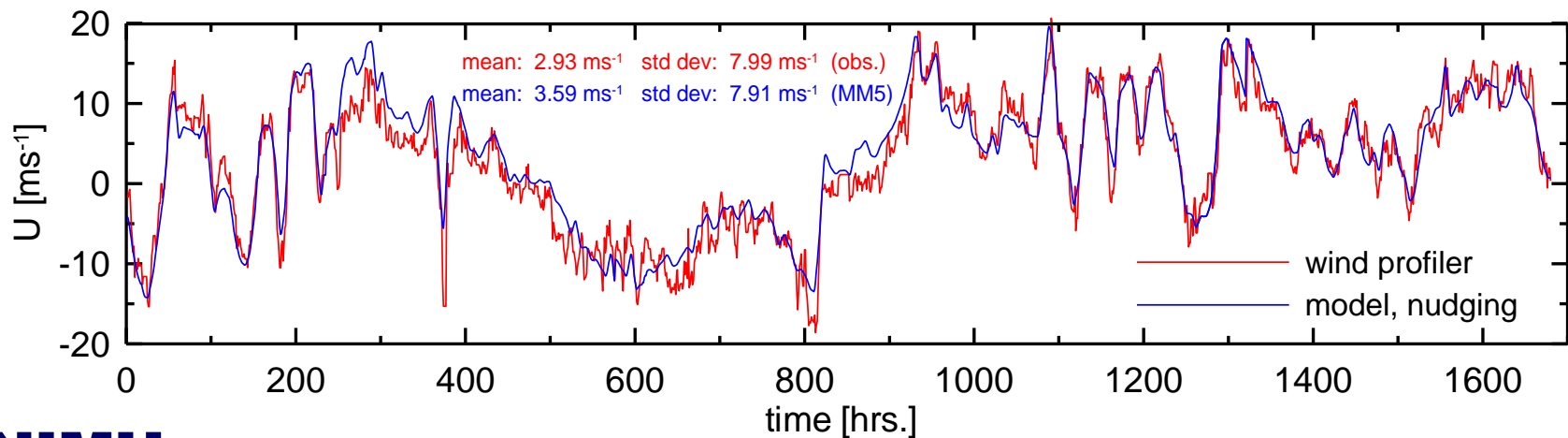
M. Quante, V. Matthias, S.-E. Gryning, E. Batchvarova, A. Aulinger, C. Chemel, G. Geertsema, B. Geyer, H. Jakobs, A. Kerschbaumer, M. Prank, R. San José, H. Schlünzen, J. Struzewska, B. Szintai, R. Wolke

CWINDE Profiler data (Myles Turp), UKMO vs *MM5*, 54 km grid resolution; full nudging

Location: Camborne,  
UK wind profiler

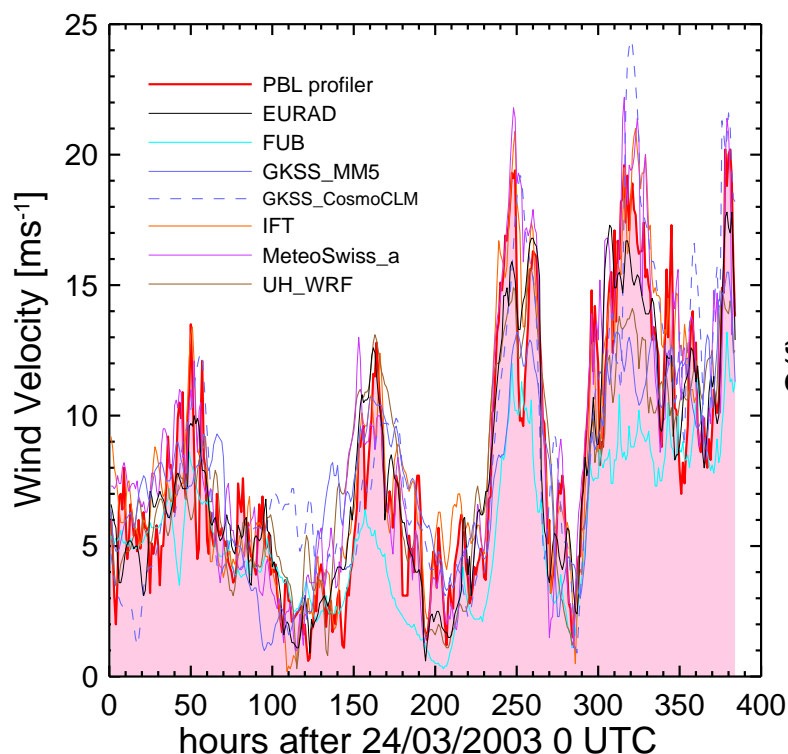


910 m, days 100 to 169 of the year 2000

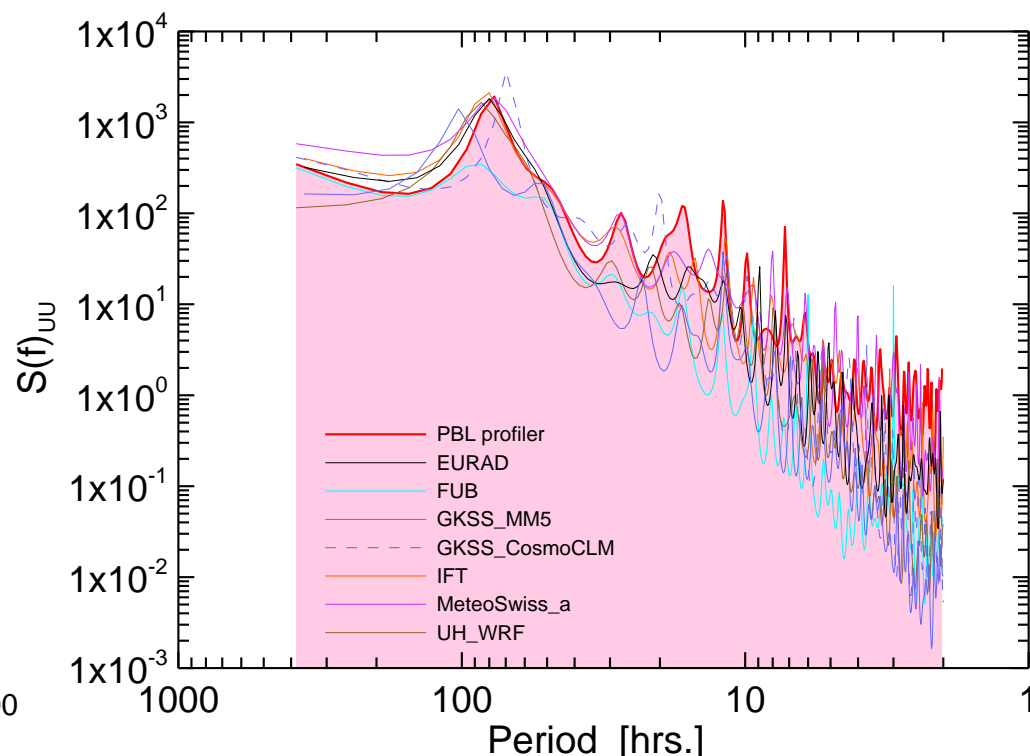


## Case studies using wind profiler data

Wind velocity at Lindenberg at about 500 m asl, 24.02.2003 to 11.03.2003,  
Wind profiler data and seven models



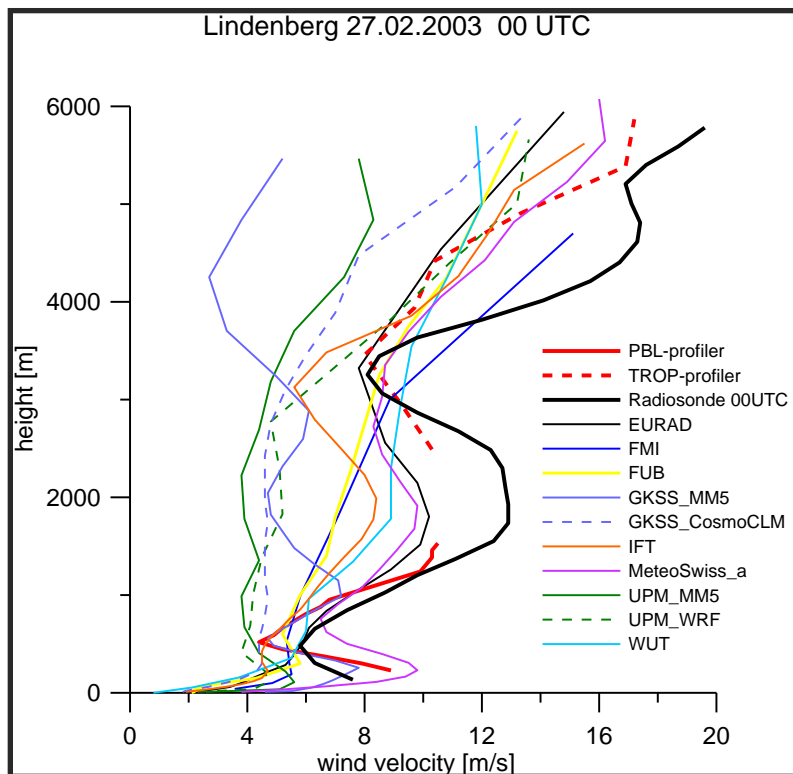
systematic deviations – phase /  
amplitude in time series



High resolution of models (< 5km) needed to  
capture intraday fluctuations – power spectra

# Case studies using wind profiler data

Lindenberg, at specific hour



Observations  
(a, b)

COSMO-CLM  
(c, d)

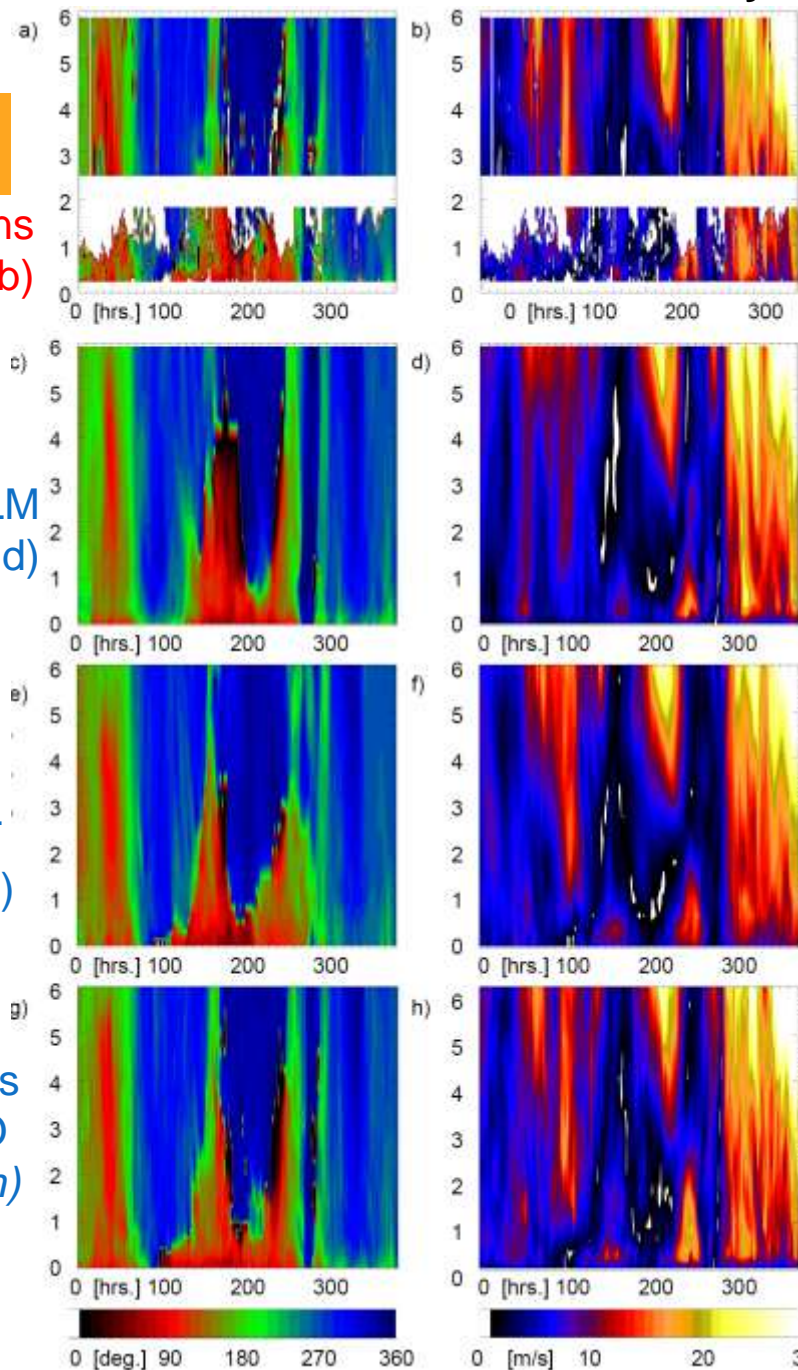
UPM-WRF  
(e, f)

Meteo Swiss  
- COSMO  
(g, h)

10th EMS,

Wind direction

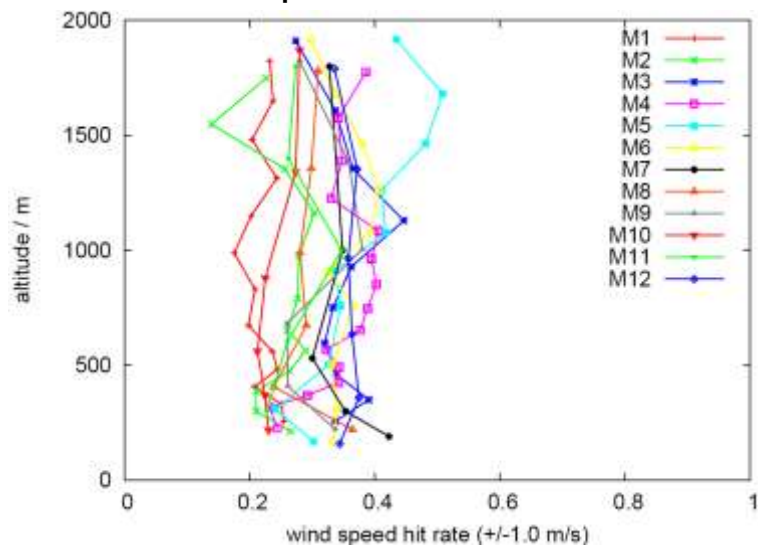
Wind velocity



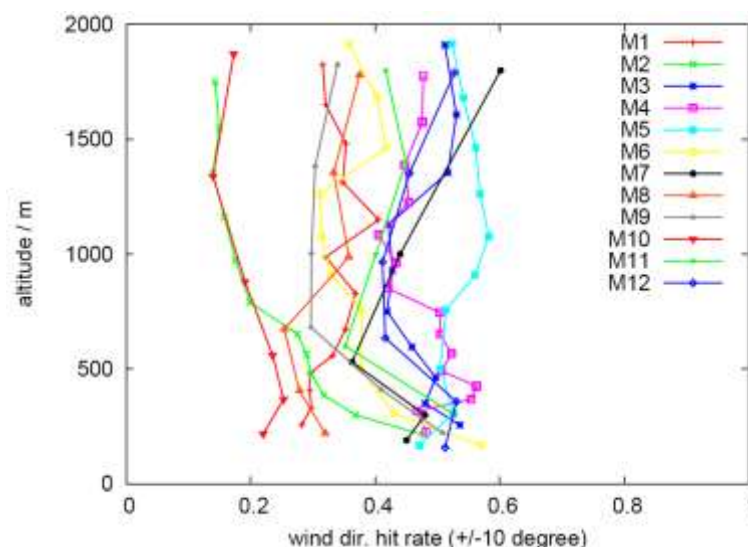


# Bulk statistics at Lindenberg, 24.02.2003 to 11.03.2003; hourly data

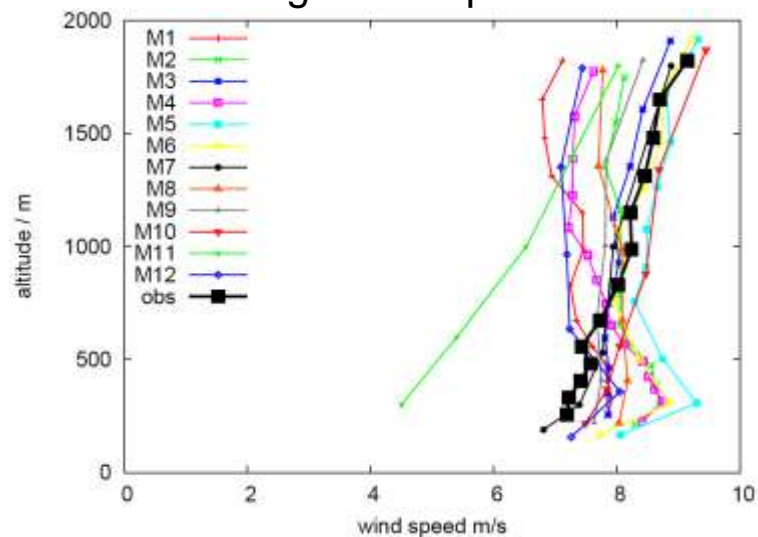
## Wind speed hit rate



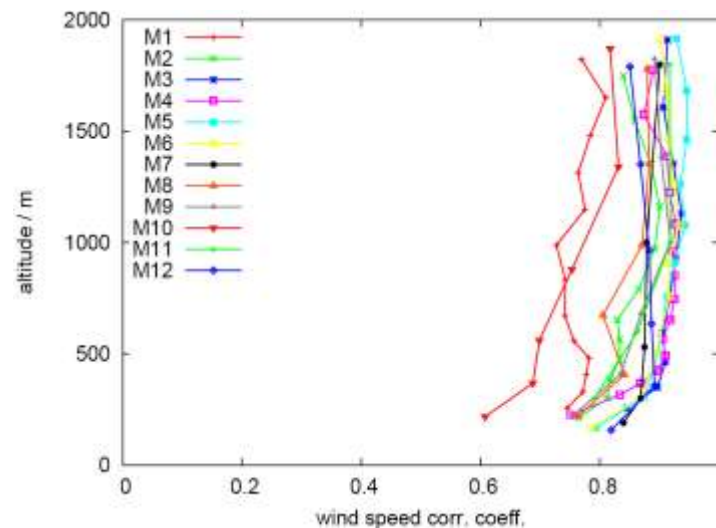
## Wind speed hit rate



## Average wind speed



## Wind speed correlation coefficient



## Climatology of the vertical profiles of wind and turbulence

**At coastal areas as Høvsøre**, the ABL is characterised by complex vertical structure and diurnal variability.

The analysis of measurements requires to distinguish marine and land flows.

The mesoscale models used need to be run on high resolution (1-2 km) to achieve correct representations of coastal line and ABL structure.

At Risoe a version of WRF is run on forecast mode





Test centres for large-scale wind turbines and related meteorology

**At Høvsøre for 10 years now**



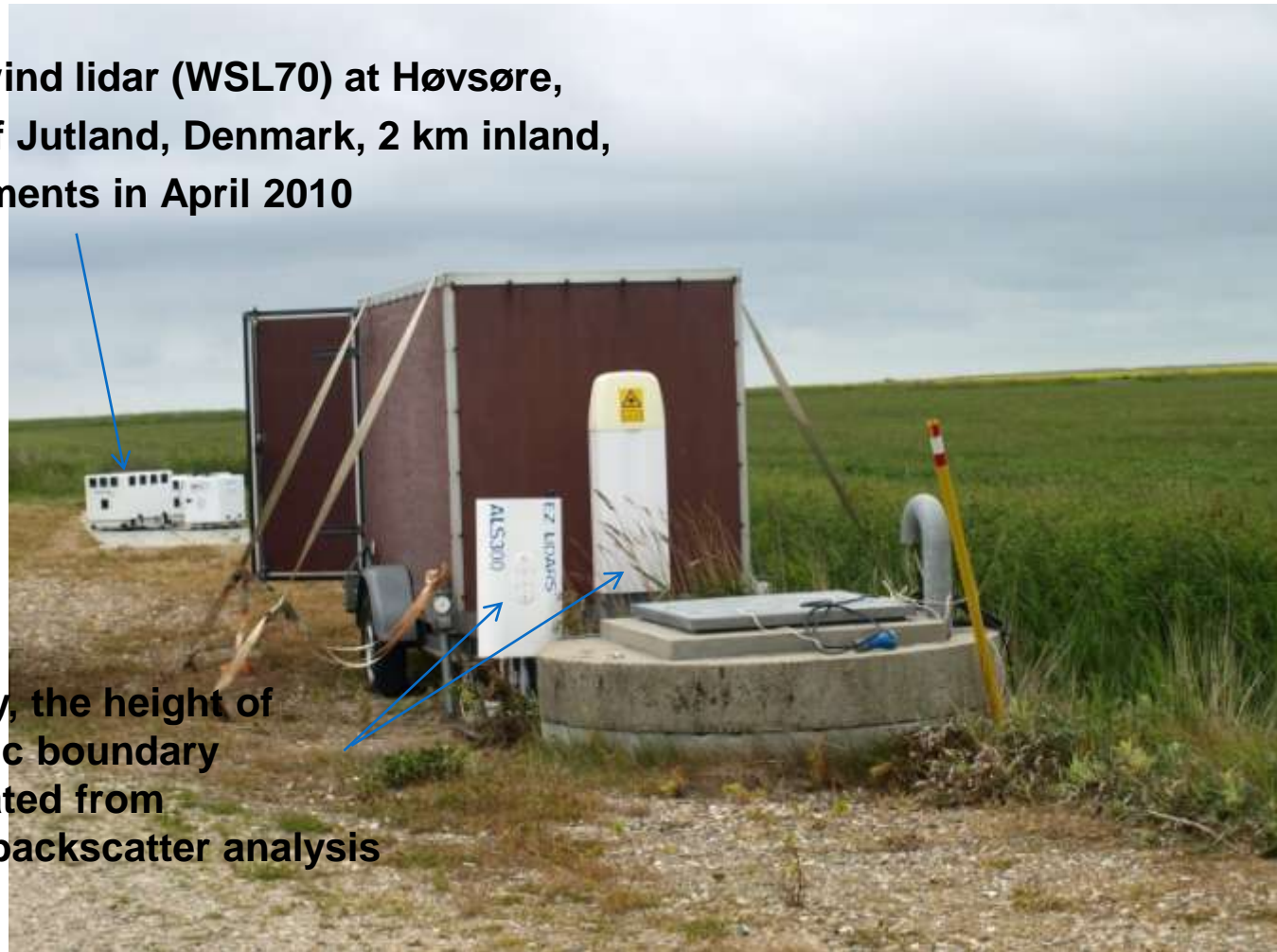
- wind turbine manufacturers can test the multi-megawatt wind turbines of the future



- scientists can test new instruments and gather long term profile measurements of meteorological parameters, both mean values and turbulence
  - on masts (up to 160 m)
  - with sodars and lidars (up to 300; 1000 m; ...)

## Climatology of vertical profiles of wind

The long range wind lidar (WSL70) at Høvsøre, the West coast of Jutland, Denmark, 2 km inland, started measurements in April 2010



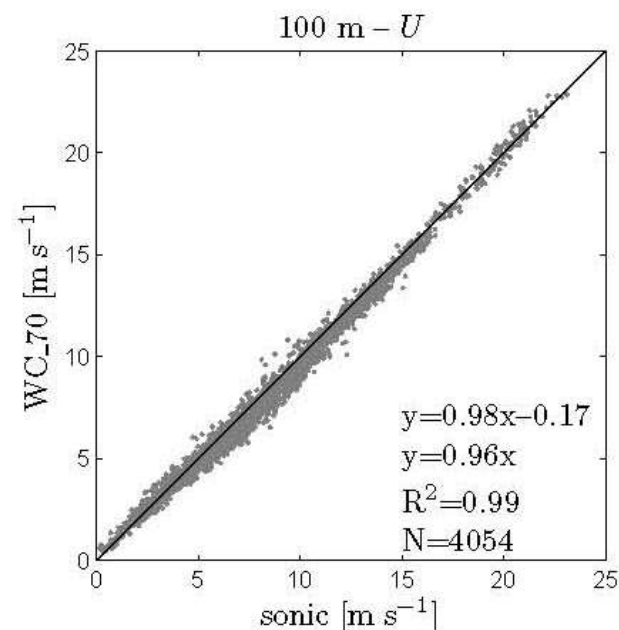
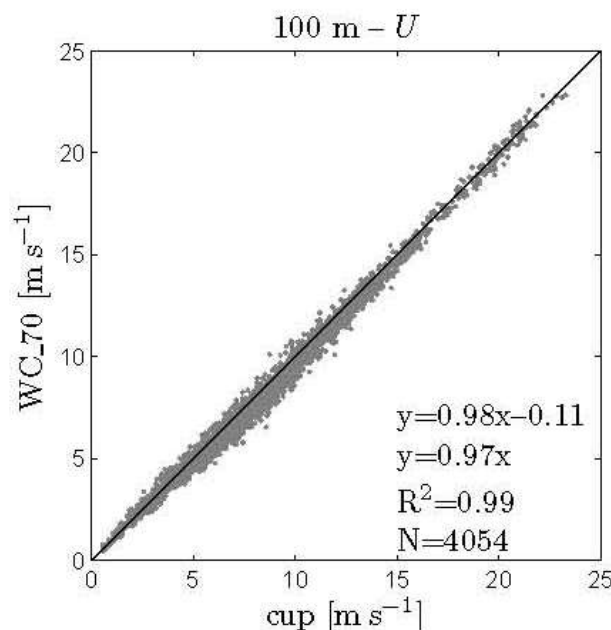
Simultaneously, the height of the atmospheric boundary layer is estimated from aerosol lidars backscatter analysis



## Climatology of vertical profiles of wind

### Wind Lidar vs cup and sonic

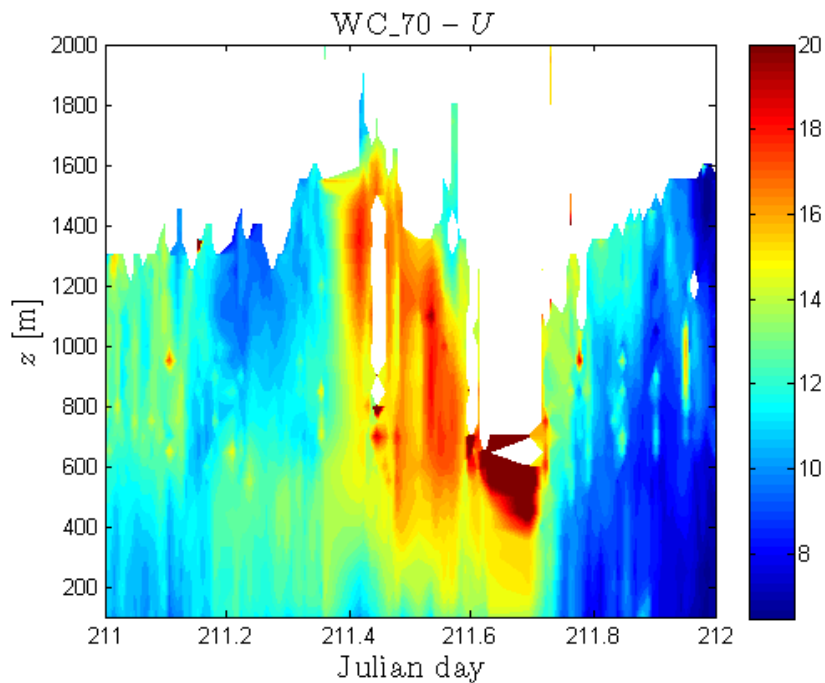
Comparison of wind speed ( $U$ ) measured by long-range lidar (100-2000 m, 50m resolution), cup anemometer and sonic,



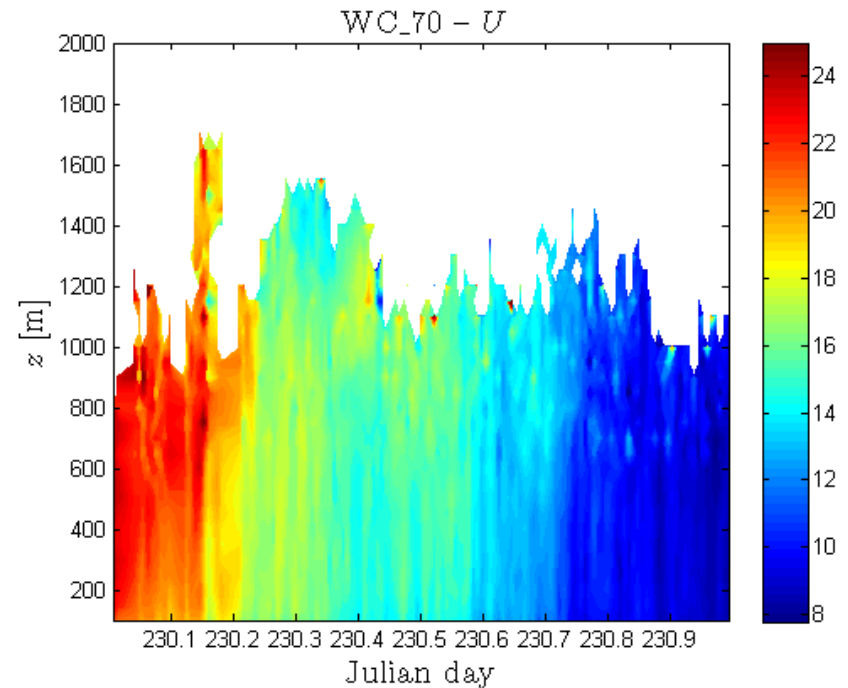
# Climatology of vertical profiles of wind

## Profiles of Horizontal wind speed

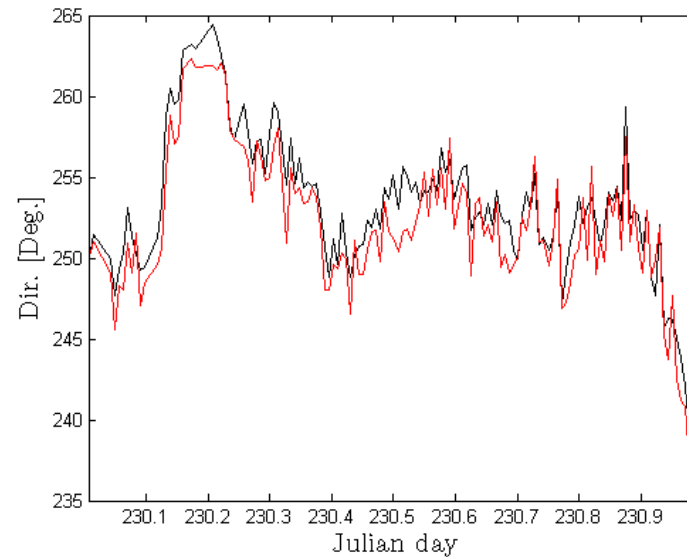
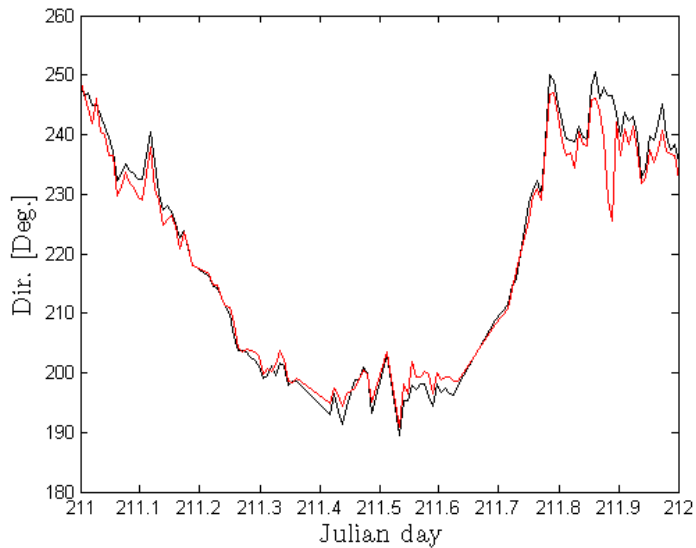
31 July 2010 (JD 211)  
Horizontal wind speed



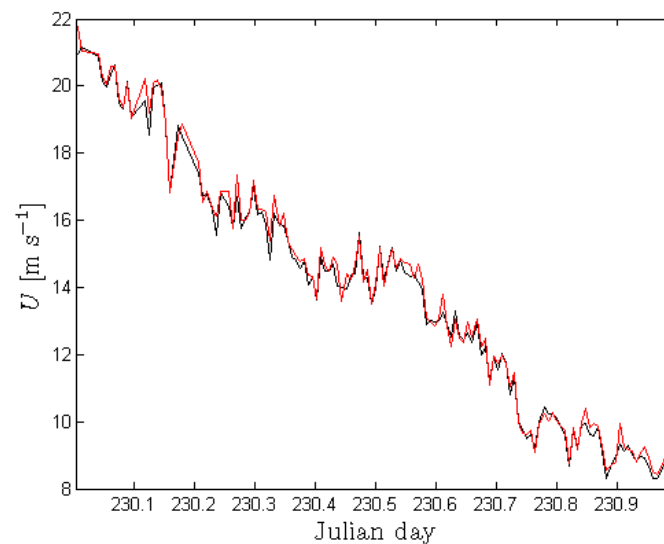
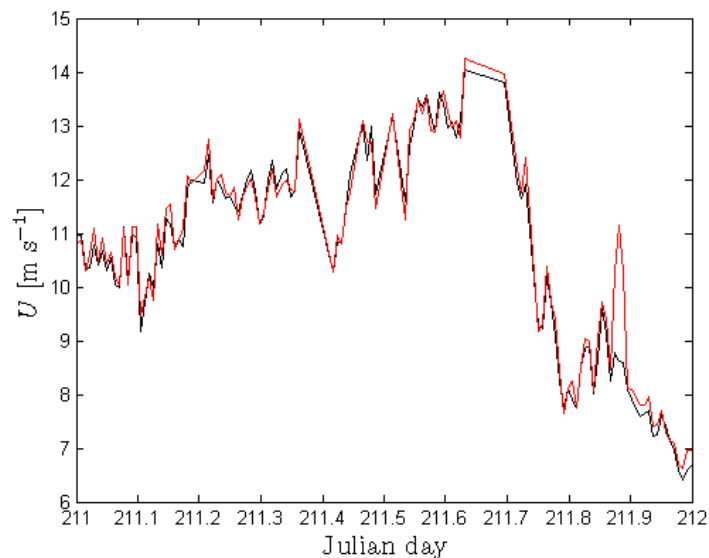
19 August 2010 (JD 230)  
Horizontal wind speed



# Climatology of vertical profiles of wind



**Wind  
direction  
and  
wind  
speed for  
31 July  
and  
19  
August  
2010  
at 100 m**



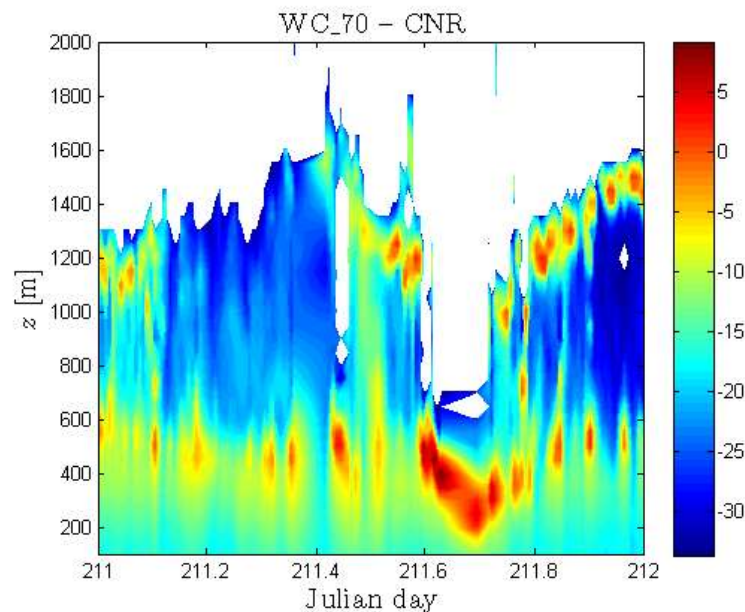
**Red  
WC\_70**

**Black  
Vane/  
Cup**

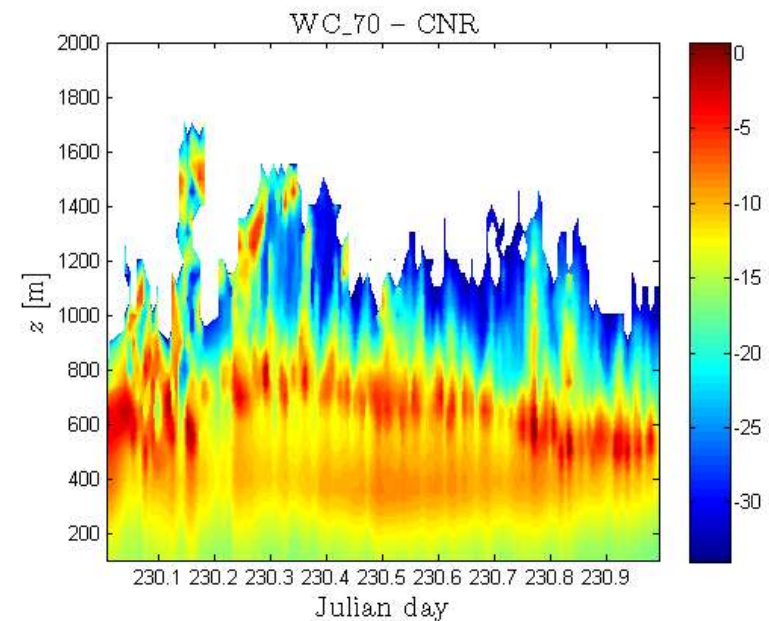
# Climatology of vertical profiles of wind

## Availability of data with regards to meteorological conditions

CNR, 31 July 2010 (JD 211)



CNR, 19 August 2010 (JD 230)

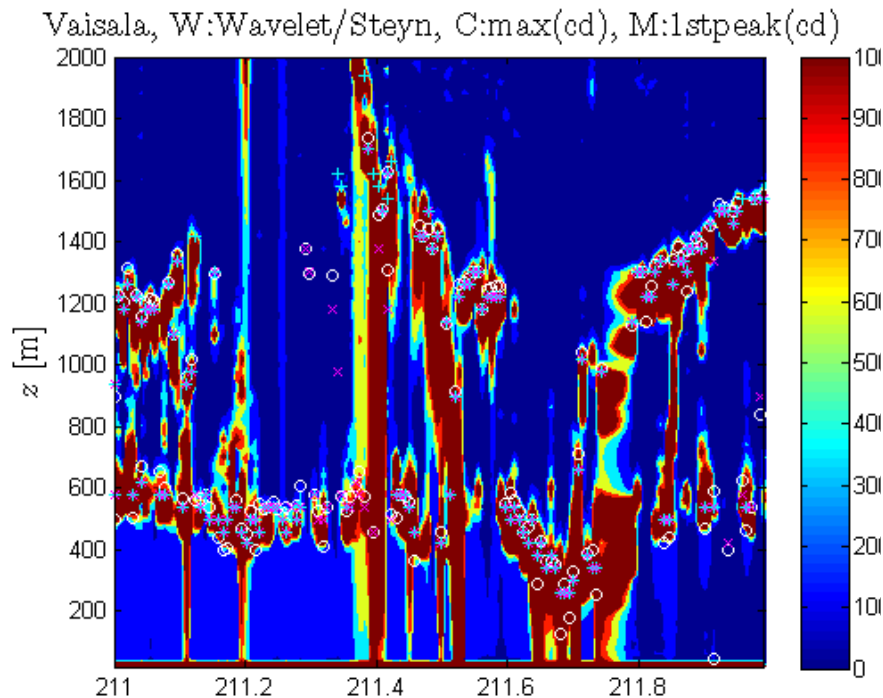


CNR, the Carrier to Noise Ratio indicates measurement quality and is calculated from raw spectra. CNR is equivalent to signal to noise ratio

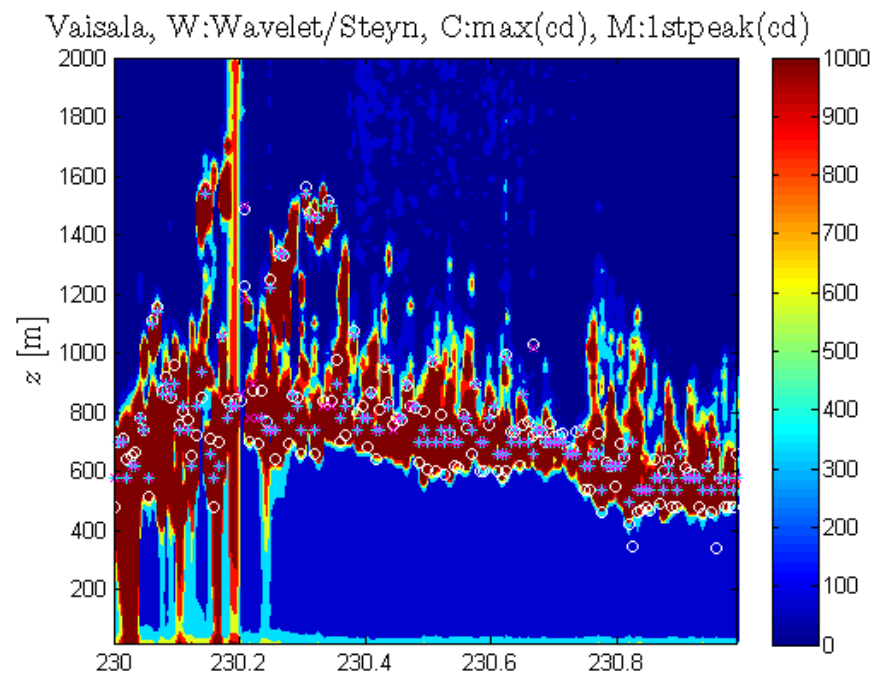


# Climatology of vertical profiles of wind

Aerosol lidars operating simultaneously give information on clouds and ABL depth



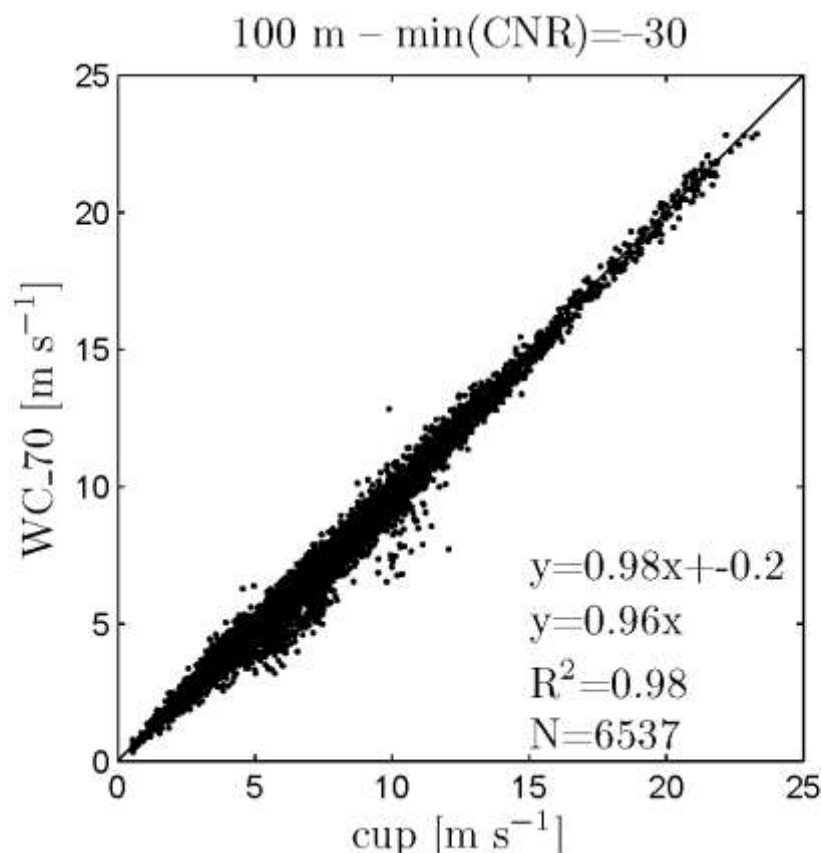
31 July 2010



19 August 2010

# Climatology of vertical profiles of wind

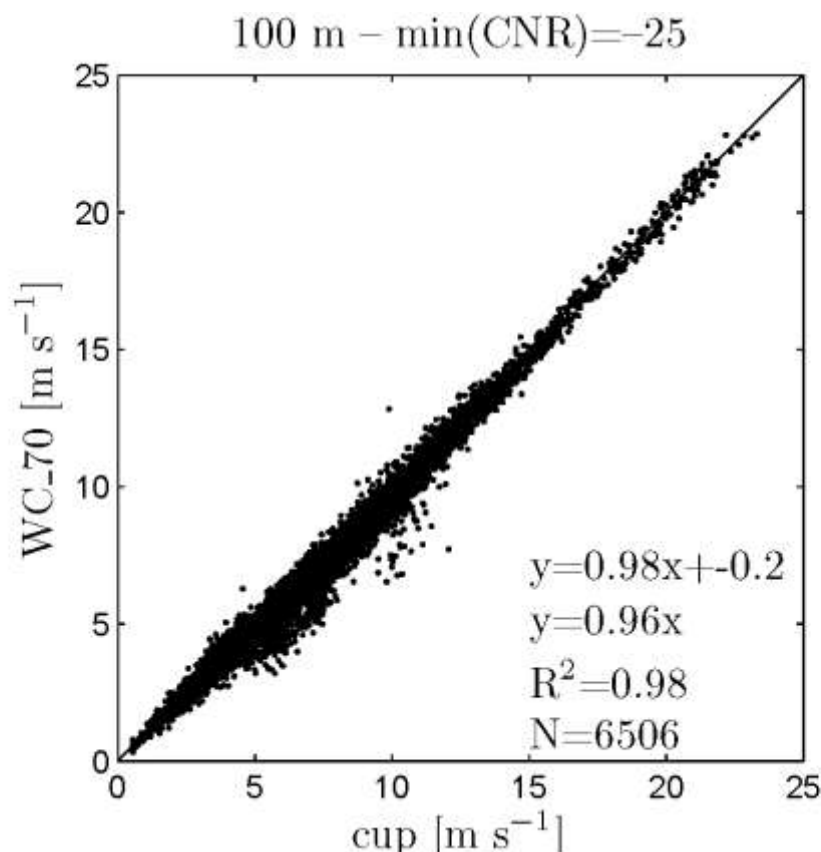
The effect of CNR value on lidar/cup comparison **-30**



# Climatology of vertical profiles of wind

The effect of CNR value on lidar/cup comparison

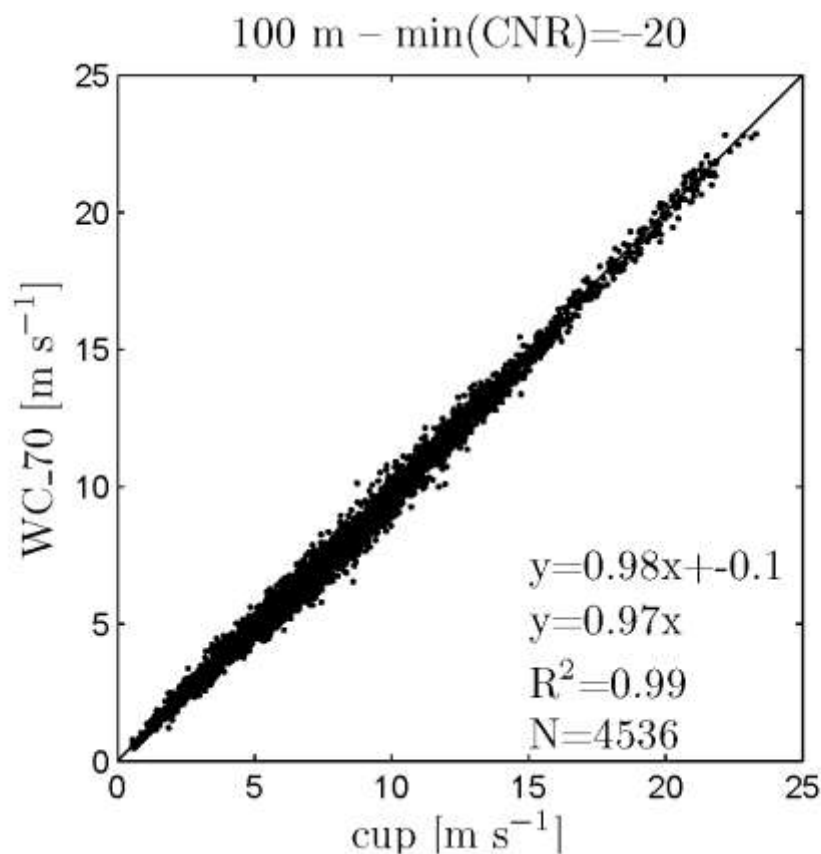
-25



# Climatology of vertical profiles of wind

The effect of CNR value on lidar/cup comparison

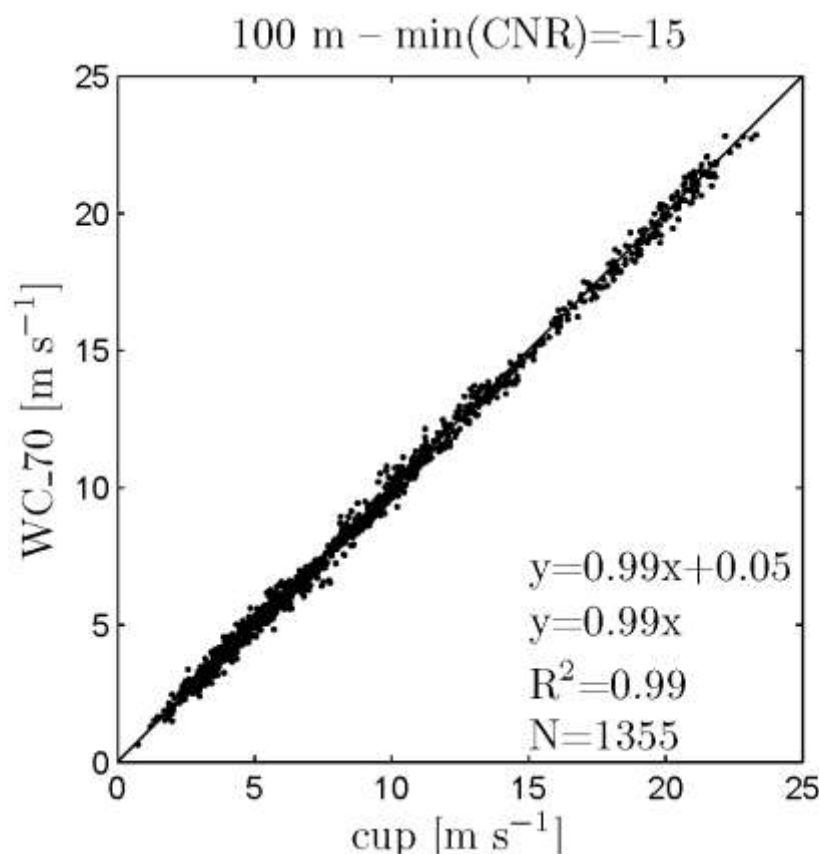
-20



# Climatology of vertical profiles of wind

The effect of CNR value on lidar/cup comparison

-15

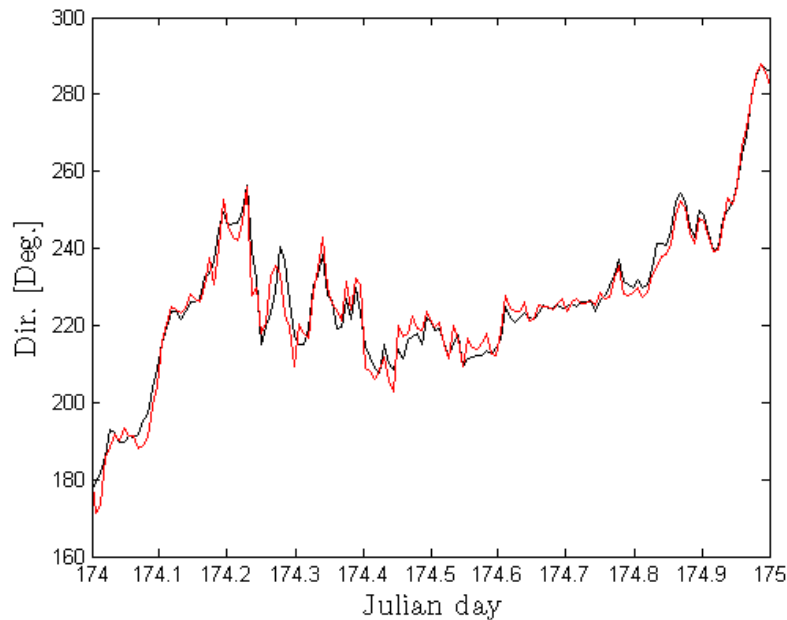


# Climatology of vertical profiles of wind

24 June 2010 (JD 174) analysis with CNR -20

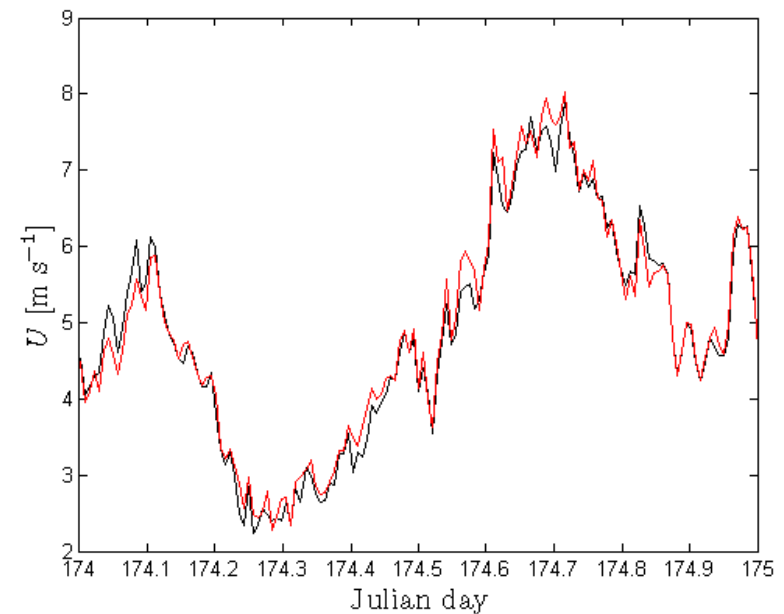
Wind direction at 100 m

Lidar / Vane

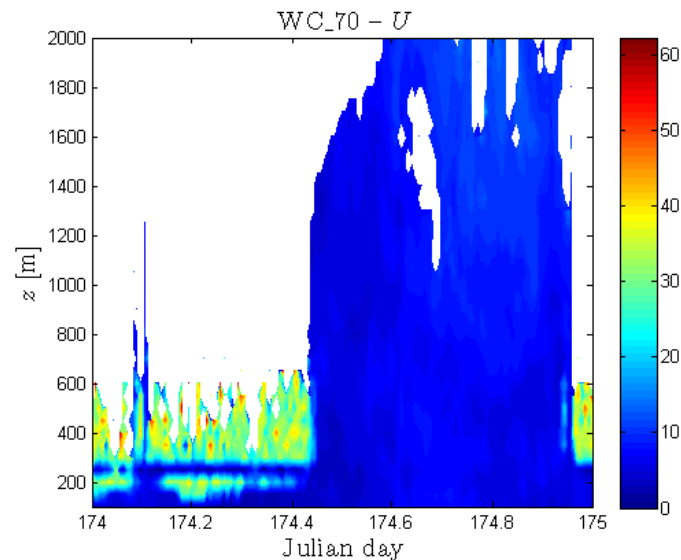
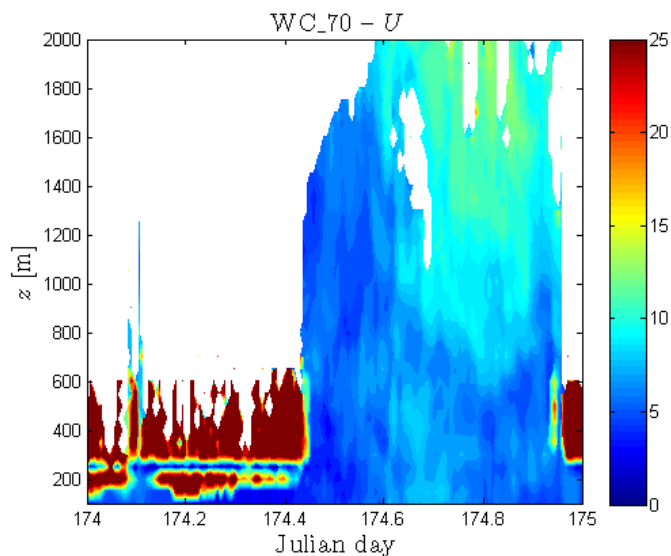
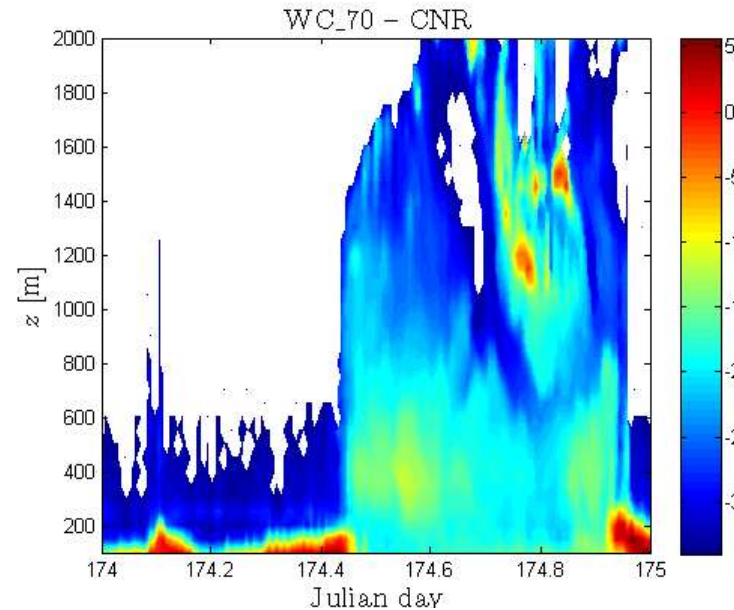
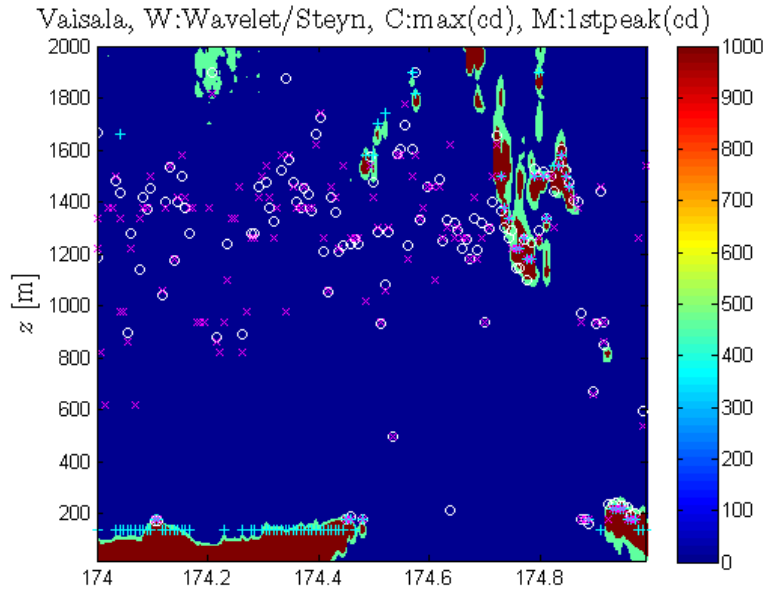


Wind speed at 100 m

Lidar / Cup



## Aerosol lidar CL31, WC\_70 CNR, WC\_70 Horizontal wind speed



Left –  
resolution  
For max  
25 m/s,

Right –  
60 m/s

## First results and future work

- 1) During the summer of 2010 Høvsøre was unique place in Europe with lidar measurements within the entire ABL.
- 2) The comparisons of long range wind lidar data with cup and sonic anemometer at 100 m on the nearby standing mast show very good agreement. This makes possible to use the data with confidence for higher levels, given the CNR ratio is appropriate.
- 3) The analysis showed that cloudy conditions were prevailing and accordingly the height reached by the wind lidar was reduced, compared to clear skies.
- 4) WRF is run on forecast mode for Denmark with high resolution (2 Km) at Risø. Comparisons will be made after further check of availability of wind lidar data.



## ACKNOWLEDGEMENT

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the Danish Council for Strategic Research,  
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VSABLA (PIEF-GA-2009-237471)

**Thank you  
for your  
attention!**